ESEARCH HIGHLIGHTS

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SEVILLE THEATRE REDEVELOPMENT PROJECT: INTEGRATED DESIGN PROCESS

Introduction

Although building designers are increasingly incorporating sustainable development criteria into their projects, these criteria are still not part and parcel of customary practices. Yet the achievement of high levels of environmental performance requires very close collaboration between a project's stakeholders. The integrated design process (IDP) described here facilitates this collaboration.

The Seville Theatre Redevelopment Project is unique in that its developer is specifically seeking the best possible response to the objectives of sustainable development, while demonstrating the economic viability of that approach.

Very early in the project, the decision was made to adopt an integrated design process (IDP). The first key step was an intensive multidisciplinary workshop, a charrette, that was held on May 2 and 3, 2003.

This type of process was developed by Natural Resources Canada as part of the C 2000 Program, as well as by the 23rd Working Group of the International Energy Agency (IEA). The process is characterized by intense interdisciplinary collaboration right from the outset in order to establish the objectives of the project and the potential for synergy between the systems designed by the various planners: the project's developer, the architects, structural engineers, electromechanical engineers, lighting designers and specialists in energy and ventilation, financial analysts, etc. Most of the time, earlier C-2000 Program charrettes focused on energy efficiency and made use of interactive energy simulations during the actual meetings. This charrette differed from that model in two ways:

- In addition to the energy efficiency issues, a broader range of questions was addressed during the charrette: urban design, architectural heritage, building rehabilitation, urban ecology, embodied energy, etc.

- The energy simulations did not take place during the actual charrette. The complexity and newness of the techniques under consideration required the collaboration of various specialists using different computer tools. That work could not be accommodated during the short time frame of the charrette. It was conducted ahead of time and the findings were discussed during the charrette. After that, the simulations were repeated based on the revisions to the concept as discussed during the charrette.

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Description of the Building Site and Program

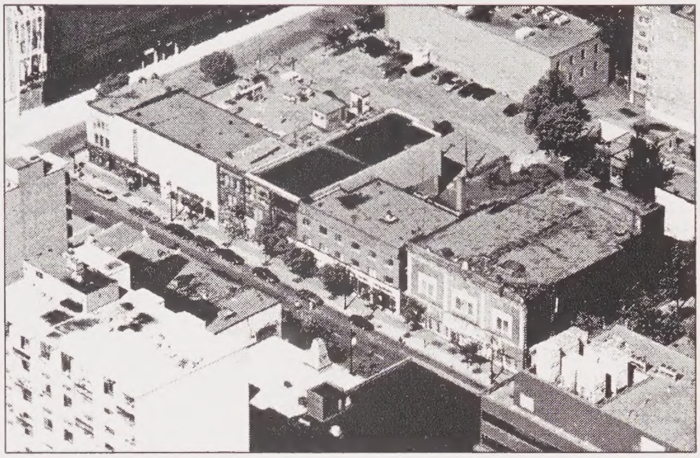

Figure 1: Aerial View of the Site

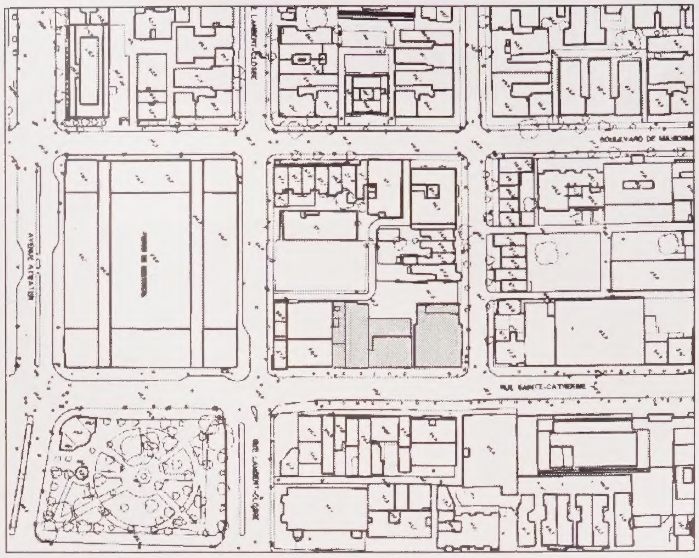

Figure 2: Site Plan Showing the Location of the Existing Buildings

The project is located in Montréal, in the commercial section of Sainte-Catherine Street between Chomedey and Lambert Closse streets, near Atwater Square and the old Forum. Even though it is situated in a dense urban area, the site has good sun exposure. A theatre erected in 1929 and two mixed commercial and residential buildings occupy the site. Two of the existing buildings are abandoned and in poor condition.

Given the speculative nature of the project, the use of the building was not entirely known at the time of the charrette. Furthermore, the program is expected to change over time. In that context, an operating program was hypothesized for the purposes of the charrette, to allow more concrete and more precise analyses and evaluations. In particular, the question of the absence or presence of housing was left open.

Occupancy	**Area in m^2**	**%**
Big box store	1,861 m^2	20.1%
Organic grocery store	512 m^2	5.5%
Other retail sales space	977 m^2	10.6%
Organic microbrewery, restaurant, café	772 m^2	8.3%
Offices (including the owner's)	1,098 m^2	11.9%
Art gallery and art studio	84 m^2	0.9%
Apartment and condominium	1,302 m^2	14.1%
Common area	2,651 m^2	28.6%
Area of building	**9,256 m^2**	**100.0%**
Indoor parking	2,651 m^2	

Table 1: Key Components of the Plan

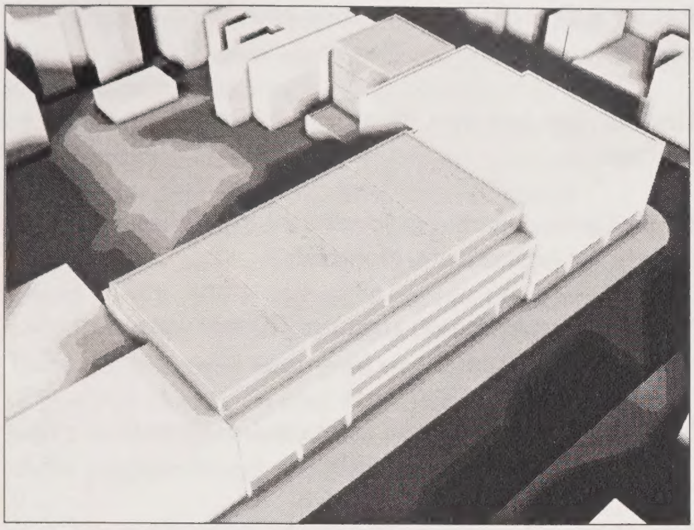

Figure 3: Pre-charrette Design Sketch 1A

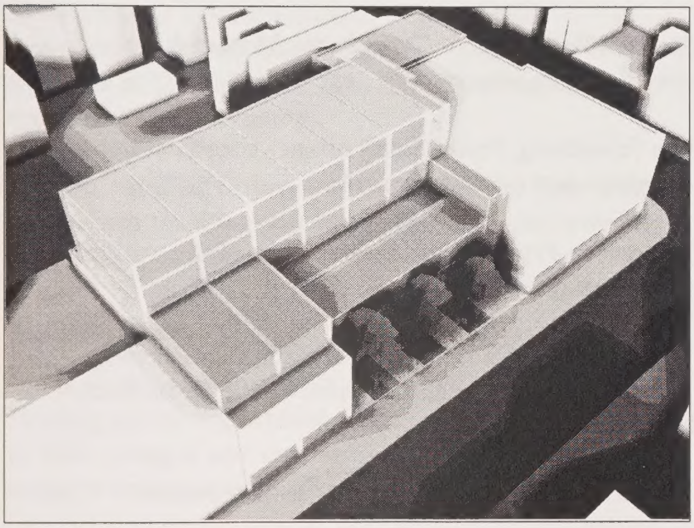

Figure 4: Pre-charrette Design Sketch 2A

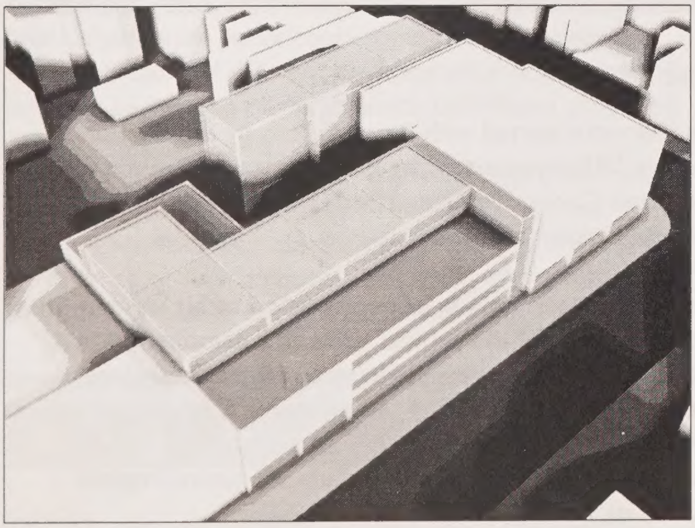

Figure 5: Pre-charrette Design Sketch 3A

Three architectural design sketches were prepared prior to the charrette. The different sketches all addressed the program described above, except for the housing, which was not included in some of the sketches. The sketches were also accompanied by outline specifications.

The three preliminary design sketches were distributed to the participants, some of whom made an initial evaluation: computer energy consumption simulations, construction cost estimates, natural lighting simulations, embodied energy evaluation.

The results of the preliminary analyses were presented at the beginning of the charrette. Also distributed were texts on the analyses of other aspects of the project, such as the structure of the existing buildings, the principles for calculating the whole life cycle costing, the heritage assessment of the buildings and the history of the neighbourhood.

This package of information served as the basis for the discussions during the charrette itself.

The first design sketch 1A reflects a building representative of current real estate developments. It is a building with a simple shape that uses current materials and techniques.

This sketch forms the benchmark for measuring the energy and environmental performance of the next design sketches. This design sketch has two variations: 1A, including some residential areas on the upper floors, and 1B, where those areas are replaced by office space.

Both sketches 2A and 3A were created for the purpose of optimizing daylight potential, solar gains and natural ventilation. Their shapes attempt to reduce the environmental impact of their erection and operation. However, the sketches do not specify any particular techniques or systems for the building's ventilation, lighting or heating systems. Those concepts were studied separately.

Selection of Charrette Participants

Since the charrette had to address topics that were more varied than the previous charrettes, a greater number of viewpoints were gathered, some of which came from backgrounds foreign to North American construction.

- Nils Larsson, Buildings Group, CANMET Energy Technology Centre, Natural Resources Canada (assistance with the integrated design process);
- Matthias Schuler, Transsolar, Stuttgart, Germany: bioclimatic engineering;
- Chris Jones, EnerSys Analytics: energy simulation using EE4 and DOE2.1E software;
- Jon W. Hand, University of Strathclyde, Glasgow, Scotland: natural and hybrid ventilation, simulations using ESP-R software;
- Andreas Athienitis, professor at Concordia University, Montréal: building envelope and energy simulation;
- Thanos Tzempelikos, doctoral student under Professor Athienitis at Concordia University;
- Christoph Reinhart, Institute for Research in Construction, National Research Council of Canada: natural light, simulations using Radiance software;
- Joseph Ayoub, CANMET Energy Technology Centre, Natural Resources Canada: photovoltaic systems;
- Martin Roy, mechanical and electrical engineer: natural and hybrid ventilation, Retscreen analyses and EE4 simulations;
- Bill Semple, Senior Researcher, Policy and Research, Canada Mortgage and Housing Corporation;
- Jamie Meil and Mark Lucuik, Athena Institute: embodied energy evaluation;
- Luc Dumais, Dessau-Soprin: structural engineering, evaluation of the existing buildings;
- Corin Flood, Project Manager, Mountain Equipment Co-op: material reutilization;
- Richard McGregor: construction cost estimates;
- Robert P. Charrette, construction economist: life-cycle costing;
- Louis Brillant, architect, Montréal: architectural heritage;
- Phyllis Lambert, architect, founder of the Canadian Centre for Architecture, Montréal;
- Walter Kehm, landscape architect, Guelph: wastewater treatment, green roofs;
- Wolfang Amelung and Julie Lefebvre, Genetron, Toronto: "Living/Breathing Walls;"
- John Sheppard, professor, McGill University, Montréal: biological wastes and brewery processes;
- Stephen Reisler, RSW Consultants, Montréal: real estate project planning and appraisal;
- Lee Schnaiberg, Projet Soleil: project coordinator, plan definition and market research;
- Jay Iversen, Projet Soleil: development of the project's image and plan;
- The entire L'ŒUF architectural team: Daniel Pearl, Mark Poddubiuk, Bernard Olivier, Martin Beauséjour, Serge Gascon;
- Catherine Trottier, architecture student: models.

The Charrette

First Day

The charrette started with presentations by the developer, Claridge SRB Investments, by Nils Larsson of Natural Resources Canada, by Daniel Pearl of L'ŒUF and by Matthias Schuler of Transsolar.

The developer made a brief presentation of his vision of the project and the project goals as a demonstration of sustainable development. He stressed the importance of the economic viability of the measures proposed. He wished to include some research projects in the building. His goal is to create a living museum for environmental techniques and practices.

Nils Larsson dealt with some questions the participants were to clarify in their environmental research. He emphasized the importance of quantifying the results of the environmental measures. He also dealt with the building's certification (by LEED, for example) as a tool for promoting sustainable development in the private sector.

Daniel Pearl briefly presented the project's architectural context and the design objectives for the charrette. The objectives were illustrated with a few examples of buildings already erected. Mark Poddubiuk continued with a brief architectural, social and cultural history of the neighbourhood.

In some ways, Matthias Schuler was the charrette's special guest. He in turn presented some examples of his projects in which control of the interior atmospheres is ensured by the overall shape and envelope of the building and by some techniques requiring very little energy.

The charrette participants were divided into four design teams. Each team included an architectural designer and an energy specialist.

Second Day

Lee Schnaiberg opened with a short presentation focusing on the importance of space flexibility to respond to later changes, and also on user participation in the project's environmental efforts.

Afterwards, the four teams presented their design sketches to the other participants. At the same time, Nils Larsson gave participants some questionnaires on the importance of different environmental objectives and on their perception of the different techniques proposed.

After the presentations by the different teams, the results of Nils Larsson's survey were presented. Lastly, the participants discussed the findings of the charrette, the importance of such a process and some of the follow-up to be performed in carrying out the project.

Description of the Concepts Developed During the Charrette

The following descriptions briefly present the design sketches and the ideas proffered by the charrette's four design teams. It was noted that three of the four teams reached very similar findings.

Team 1: "Montréal's Breathing Heart"

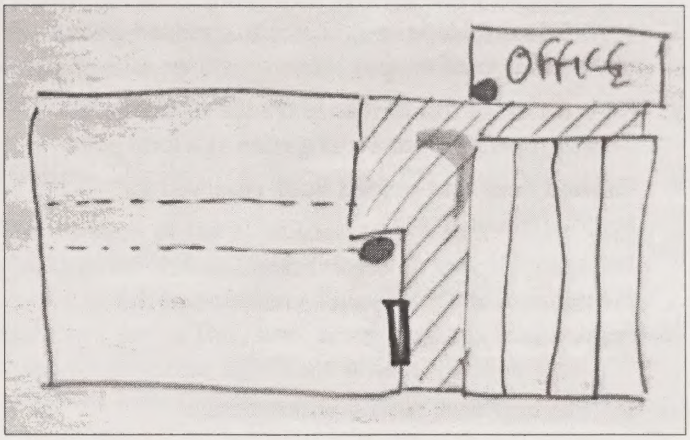

Figure 6: Ground Floor Plan, Team 1

- Create an indoor space that is not just an entrance
- Give the impression that the vessel has docked
- An inspiring space
- Common area for a viable environment
- Intercommunication
- Activity uninterrupted by the varied uses at different times inside the theatre: sales during the day, music or theatre at night
- A new market place
- Inside atmosphere created by the users
- Draw the attention of passers-by on Sainte-Catherine Street
- Interior showcases
- Positive effect of natural lighting on the sales
- Direct presence of the shops on the street

Team 2: "Ville Soleil"

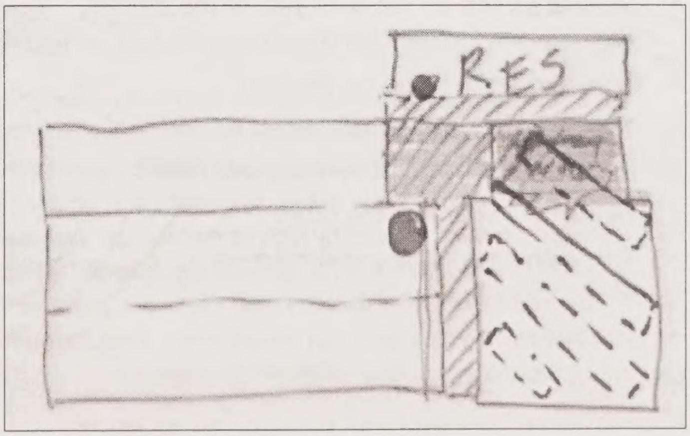

Figure 7: Ground Floor Plan, Team 2

- Maximization of the solar potential
- Photovoltaic panels facing south
- New balcony inside the theatre, suspended from the existing roof trusses
- Re-creation of the former entrance to the Seville Theatre, opening onto a wall garden as a focal point
- Ground floor and second floor reserved for commercial uses
- Shallower depths on the third and fourth floors for the natural lighting and ventilation of the residential and office space.

Team 3: "Perception and Awareness"

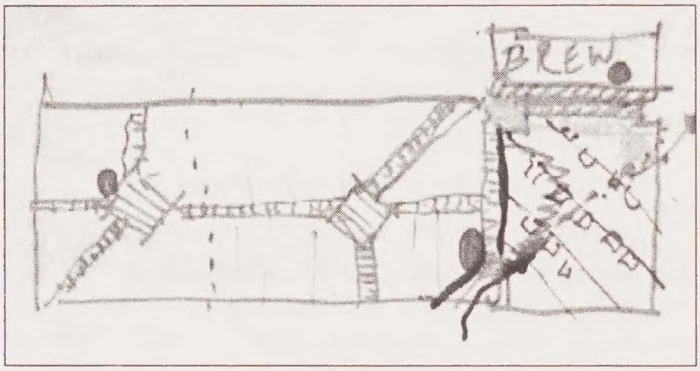

Figure 8: Ground Floor Plan, Team 3

- Cultural diversity
- Use of wood
- Creation of a green space in Montréal
- Permeability of the facade overlooking Sainte-Catherine Street, like a railway station or "Swiss cheese"
- Trees in the sidewalk irrigated by the rainfall collected on the roof
- Vertical garden on the back wall of the theatre, remains of a former church
- Reuse of rocks found on the site
- Skylights and photovoltaic panels on the roof
- Trapping of the rainfall by the green roof
- Return of Nature to the City
- Possibility of walking around the wall of the church
- Interior courtyards

Team 4: "Sungrabber"

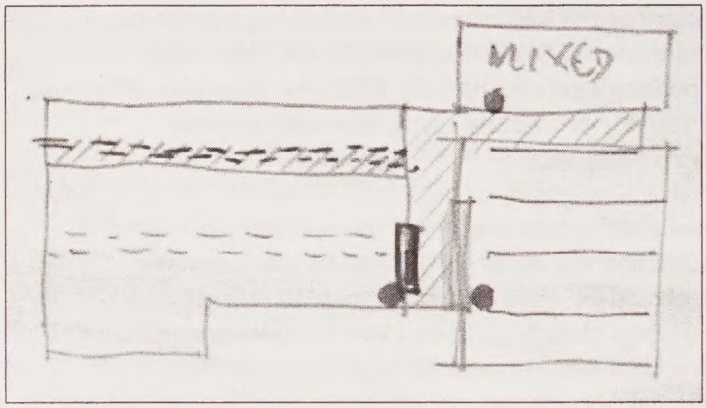

Figure 9: Ground Floor Plan, Team 4

- Skylights, photovoltaic panels and windscoops on the Seville Theatre roof
- Atrium creating a buffer between the Seville Theatre and the new construction
- Living wall in the atrium
- Wall of water in the atrium to control indoor air humidity
- Facade set back from Sainte-Catherine Street
- Balconies within the Seville Theatre

Post-charrette Work

L'ŒUF developed a new design sketch, designated 4A, based on the ideas shared by the three charrette teams whose sketches were similar. The sketch was distributed to those doing the simulations and evaluations.

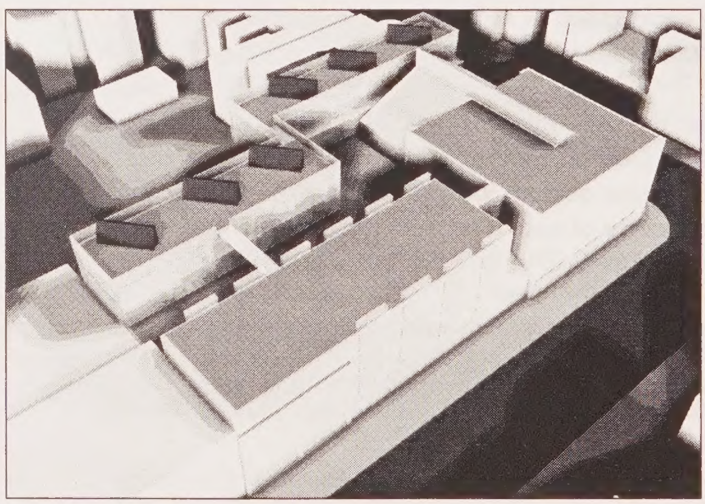

Figure 10: Post-charrette Design Sketch 4A

The final energy performance evaluation was a major challenge for the engineers. Some of the environmental techniques considered cannot be modelled directly by DOE2 or EE4 software. The techniques were evaluated separately and the findings of the analyses were then incorporated into the global model. Other techniques could not be evaluated satisfactorily because of their complex interaction with other project components. In some cases, the experts' opinions differed, indicating that further examination is required.

Chris Jones was in charge of the simulations and Martin Roy, helped by L'ŒUF, coordinated the work of the different specialists. The simulations by Chris Jones were incorporated into the findings of the following work:

- Using their own computer models, Andreas Athienitis and Thanos Tzempelikos evaluated the double-skin façade and the underground piping for heating or cooling exchanged air. They also evaluated the effect of the vent stacks and the Trombe wall.
- Jon Hand simulated the air and heat transfer in the Seville Theatre and in the area adjacent to the atrium, using ESP-R software.
- Martin Roy supplied information on the active geothermics, on domestic hot water solar heating and on a humidification system using an architectural water wall (with the help of Matthias Schuler).

Evaluation of the Different Environmental Techniques

During the preparation of the charrette, certain key environmental techniques were identified. They were evaluated before the charrette as well as after it. This evaluation allowed these techniques to be classified into two groups: on the one hand, the techniques that are economically justifiable because of the savings they make possible, and on the other hand, the techniques that, while helping to reduce a building's adverse impact on the environment, result in additional costs that are not recoverable in the current context.

Geothermal Heating or Cooling of Replacement Air

This technique does not require complex equipment and has a promising potential. The additional costs were estimated to be less than $100,000 and can be depreciated in less than 6 years. In some cases, integrating it may require some modifications to the shape of the building.

Solar Chimneys

Exhaust air vents using solar energy were evaluated. The findings indicate that this technique is not really cost-effective: its depreciation requires more than twenty years.

Hollow Walls

The concept of the sophisticated hollow exterior wall proposed by Andreas Athienitis yielded some contradictory results in the respective analyses by Andreas Athienitis and Chris Jones. The latter considers that this component does not generate significant savings, while Andreas Athienitis feels that the hollow wall can be depreciated in eight years. The definitive evaluation of this component will require more work and will depend in part on the interior air exchange rates.

Hydraulic Geothermy

This technique is increasingly widespread in Canada and demonstrated its relevance in this instance, too. Depreciation takes roughly six years. Its integration into the building is simple.

Natural Lighting

Christoph Reinhart evaluated the natural lighting in some of the project areas. His evaluation showed significant potential for "daylighting" the office space. For those areas, he also suggested some layout strategies in which the workstations are located close to the exterior walls and the areas farthest from the natural light are assigned the support functions. He also suggested the use of horizontal interior and exterior blinds as a more economical and effective lighting alternative than the hollow wall with solar screens suggested by the ventilation experts.

Passive Solar Heating

The post-charrette sketch attempts to maximize the passive solar heating potential. Although the evaluation of this design sketch showed much greater energy efficiency than the pre-charrette design sketch 1A, it is difficult to quantify how much of that efficiency is attributable to the direction of the fenestration, the Trombe wall and the increased thermal mass. Furthermore, the increased thermal mass contributes not only to heat comfort but also to programming flexibility and soundproofing.

Green Roof

In spite of earlier publications that attribute reduced thermal transfer through a green roof, our findings did not demonstrate a significant effect. This might be explained by the small quantity of those exchanges in a customary roof. Moreover, the cooling loads in the post-charrette scenario are reduced by the use of other passive measures. The contribution of the green roof to the reduction of the building's environmental impact occurs at other levels where there is no direct financial impact for the owner: rainwater management, environmental renewal, reduction of urban pollution, etc.

Water Wall and Interior "Breathing" Wall

The water wall uses a large indoor area of running water with its temperature controlled so that it absorbs or gives off humidity. This functional and decorative component was not evaluated in detail after the charrette because of its complexity.

Wolfang Amelung's interior "Breathing Wall" aroused a great deal of interest during the charrette. Even though its cost is substantial and it does not generate measurable savings, the project's developer remains interested in using this component as a public attraction and as a subject of research.

Construction Costs and Evaluation of Embodied Energy

The results of the post-charrette analyses were grouped into five different scenarios:

1A:	Basic building, reflecting customary practices. This scenario is used as a reference for evaluating the performance of the other scenarios.
4A reference:	Improved building shape but without energy efficiency measures. The construction techniques reflect customary practices. This scenario tool is used as a reference for the evaluation of the scenario 4 variants hereunder.
4A CBIP improved:	Improved building shape plus energy efficiency measures meeting the minimum requirements of the CBIP program.
4G green (LCC):	Improved building shape, energy efficiency measures and environmental techniques justifiable by the whole life cycle cost. This scenario reflects a combination of optimally cost effective environmental technologies.

Material Reutilization and Embodied Energy Evaluation

Jamie Meil and Mark Lucuik of the Athena Institute evaluated the total embodied energy, the greenhouse gas emissions and the pollution emitted for pre-charrette design sketch 1 and for the post-charrette design sketch. The post-charrette design sketch makes it possible to:

- Reduce embodied energy by 47%;
- Reduce air pollution from the building by 11%;
- Reduce water pollution by 98%.

The Athena evaluation further identified that the preservation of the structure of the Seville Theatre has the greatest impact on embodied energy. The reutilization in situ of the steel structure and the clay bricks also helps. However, the on-site crushing of concrete requires a great deal of energy and offers few advantages.

Solar Heating of Domestic Water

The cost effectiveness of using solar heat for domestic water heating depends on energy costs and on government grants. This technology has proven itself and will likely be incorporated into the project.

Photovoltaics and Building Integrated Photovoltaics

In the present context, photovoltaic cells produce electricity at a cost much higher than the current rate in Montréal. The high cost of the cells may, however, be offset by their integration into the materials of the building envelope. Andreas Athienitis, in particular, considers that this application has great potential.

Code	Components	1A	4A reference	4A CBIP improvement	4G green (LCC)	4G green plus
A	Foundation	837,064	853,393	853,393	871,878	871,878
B	Frame	2,813,520	3,139,121	3,487,912	3,887,032	4,268,543
C	Interior	2,147,116	2,141,950	2,141,950	2,063,941	2,063,941
D	Services	2,766,275	2,657,339	2,952,599	2,730,159	2,730,159
E	Equipment and furnishings	65,000	65,000	65,000	65,000	65,000
F	Special construction and demolition	160,000	160,000	160,000	810,000	1,340,351
G	Site landscaping	144,709	134,954	134,954	134,908	134,908
	Net construction cost	8,933,684	9,151,757	9,795,808	10,562,918	11,474,780
K	Administration and profit	1,072,042	1,098,211	1,175,497	1,267,550	1,376,974
L	Contingency	1,000,573	1,024,997	1,097,130	1,183,047	1,285,175
Underground parking included						
	Construction cost	11,006,299	11,274,965	12,068,435	13,013,515	14,136,929
	Gross floor area	106,000	95,300	95,300	95,300	95,300
	Cost per square foot	104	118	127	137	148
	Cost per square metre	1,116	1,272	1,361	1,468	1,595
	Cost comparison per ft^2	-12%	Base	7.0%	15.4%	25.4%
Underground parking not included						
	Construction cost	10,111,299	10,379,965	11,173,435	12,118,515	13,241,929
	Gross floor area	88,100	77,400	77,400	77,400	77,400
	Cost per square foot	115	134	144	157	171
	Cost per square metre	1,234	1,442	1,552	1,683	1,839
	Cost comparison per ft^2	-14%	Base	7.6%	16.7%	27.6%

Table 2: Comparison of Construction Costs for the Different Scenarios

Scenarios	Difference in Construction Cost as a percentage	Difference in Energy Savings as a percentage
1A	-13%	-
4A reference	0%	0%
4A CBIP improvement	8%	40%
4G green (LCC)	16%	70%
4G green plus	26%	72%

Table 3: Construction Costs and Energy Savings Comparison

Comments

- The higher construction cost of the different variants of scenario 4 as compared with scenario 1A is primarily due to the envelope of the larger, more costly building. Those costs are the result of a building shape that seeks to maximize the potential for natural light and passive solar heating.

- Depreciation of the additional costs of the 4G green (LCC) scenario in relation to the reference 4A scenario is between 10 and 11 years.

- The additional costs of the 4G green (LCC) scenario as compared with the 4A CBIP improvement scenario take 14 years to depreciate, an excessive time frame for most real estate developers. Those costs are in large part due to the concrete structure: its advantages are not limited to energy efficiency. However, the prolonged depreciation time indicates that some of the less efficient environmental techniques must be optimized or eliminated during a later review of the project.

- The depreciation of the additional costs of the 4G green scenario as compared to the 4A reference scenario requires roughly 19 years, making that scenario economically unjustifiable.

Ranking of the Project Objectives, Risk Assessment and Efficiency of the Environmental Techniques

One of the important lessons learned from experience with the C-2000 program is that, right from the beginning of the project, it is necessary to define what specific environmental objectives are to be achieved.

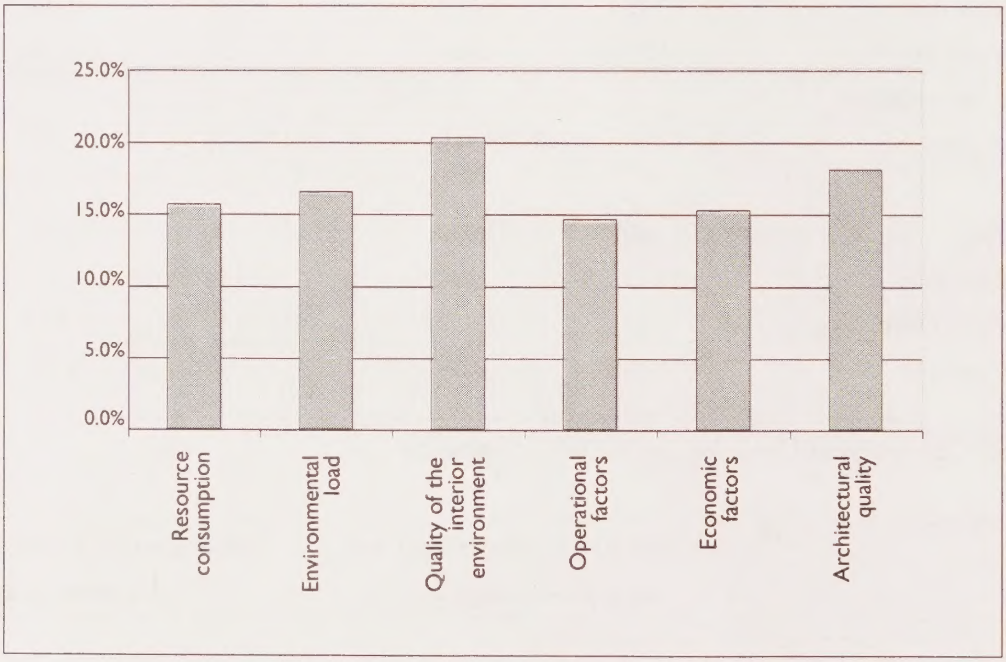

Figure 11: Participants' Evaluation of the Relative Importance of the Different Environmental Criteria

The above chart illustrates the results of the survey conducted during the charrette. Within these averages, the various groups of participants differed on certain points:

- The developer assigns more importance to the concept of savings and to the quality of the interior environment.
- The architects assign more importance to resource consumption and environmental loads and less importance to operating criteria.
- The energy specialists assigned more importance to the quality of the interior environment and to the economic factors.

This survey was conducted at the end of the charrette. Thus, it did not affect the design work by the teams or the final discussions on the second day.

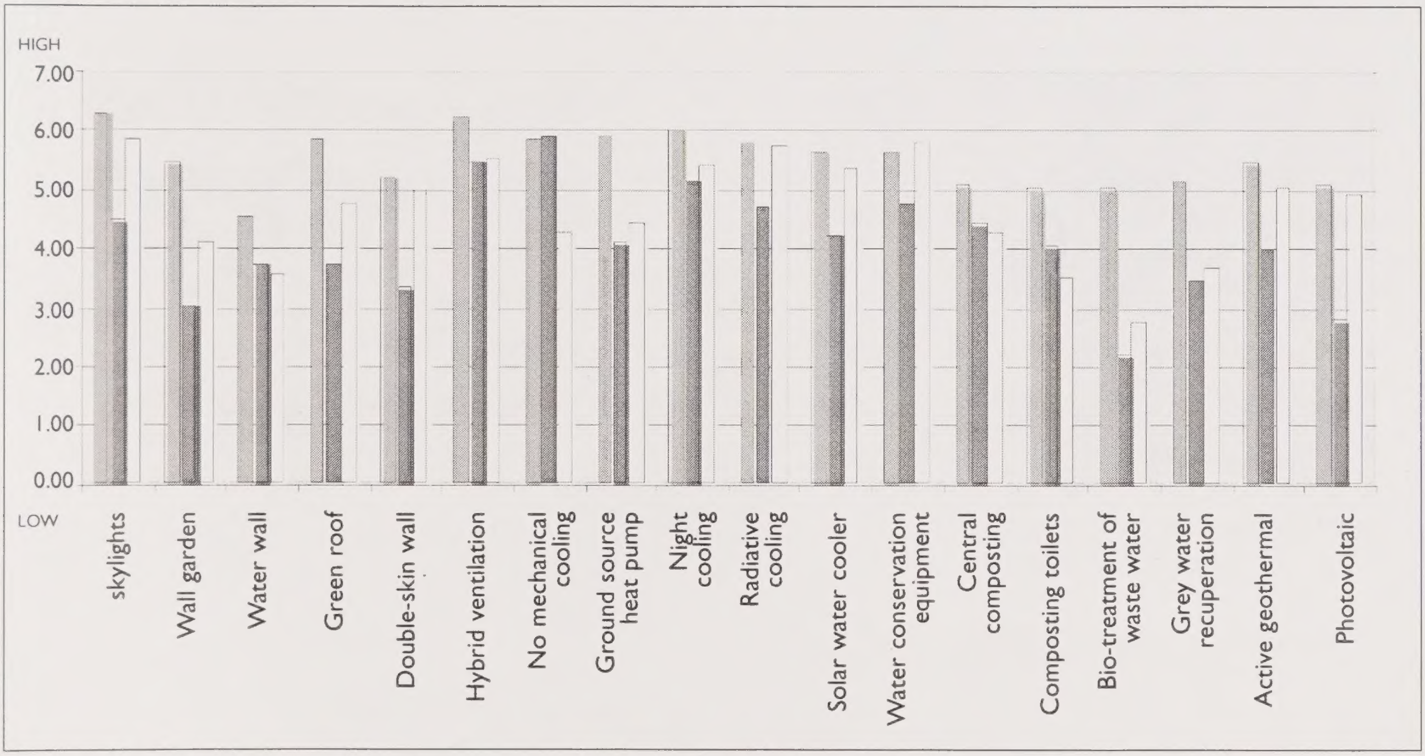

Figure 12: Participants' Evaluation of the Costs, Performance and Risk Associated with Different Environmental Techniques

The second chart (above) illustrates the participants' opinions on the cost ▒, performance ■ and risk □ of the different techniques proposed where 0 equals lowest cost, performance and risk, and 7 equals the highest values for these factors.

It is partly in response to the results of this survey that certain environmental techniques were abandoned during the post-charrette evaluation because their economic relevance seemed improbable: photovoltaic panels, wastewater treatment or the water wall to control indoor humidity.

Conclusions

The energy simulations showed some impressive and unexpected performance levels, immediately demonstrating the value of the integrated design process.

Although the developer participated actively in the charrette, no representatives of the building's eventual users were included. They had not yet been identified and therefore could not have been invited. Ignoring their concerns made it easier to explore innovative techniques, but perhaps at the expense of the project's economic feasibility. The exception to this omission was Corin Flood of the Mountain Equipment Co-op stores. His way of looking at the project was notably different from that of the other participants. In his opinion, the operating and financial demands of business operations impose some restrictions that were overlooked in this charrette.

The participation of the European experts had a great influence on the charrette. By sharing their built-environment experience, the experts allowed us to evaluate the real potentials and risks of techniques that are still uncommon in our context.

Analysis of the whole life-cycle cost for the various techniques made it possible to carefully evaluate their economic relevance, a criterion fundamental to the objectives of the project's developer. Several of the techniques suggested can be depreciated in less than eight years.

Note

This paper is an abridged version of the *Seville Theatre Redevelopment Project, 2153 2197 Sainte-Catherine Street West, Montreal: Integrated Design Process (IDP) Description and Evaluation Final Report,* initially submitted to CMHC on November 4, 2002. This summary was written by Bernard Olivier and Marie France Bourassa.

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